Transmission grating spectrometer for broadband diagnosis of EUV sources

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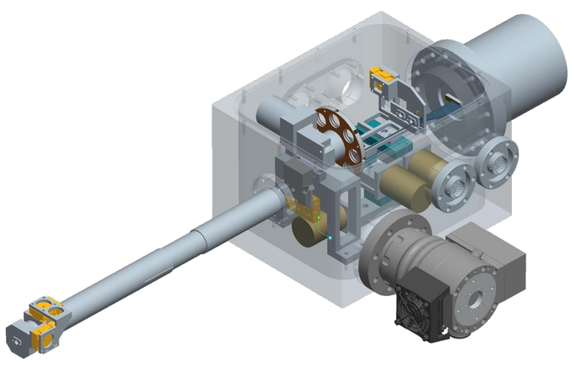
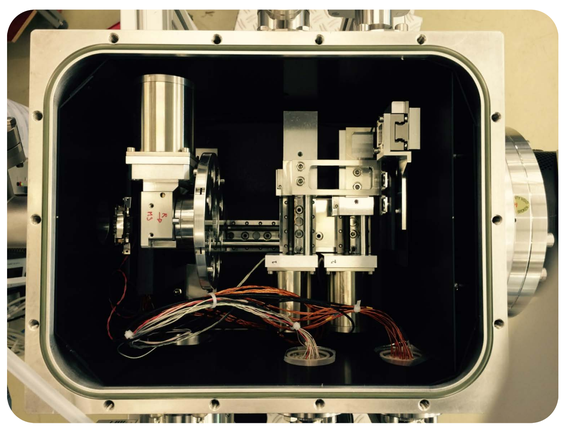
Motivation

- Comprehensive spectral characterization for critical optimization of EUV sources
- Measurement of both in-band and out-of-band spectrum of sources from EUV to UV wavelengths
- Compact spectrometer for cross comparison of sources
- Reproducible fabrication of high density transmission gratings, up to 10.000 periods/nm, to enable high resolution in the EUV wavelengths

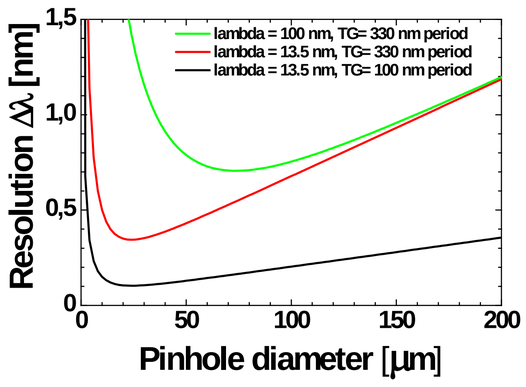
Compact High-Resolution Spectrometer for VIS, UV, EUV

- Easy alignment:
  - Computer-controlled positioning of components
  - GUI to control the optics and record/process spectrum
- Vacuum rating: down to 10^{-6} mbar
- Integrated shutter to block light beam
- Filter wheel to select specific wavelength ranges

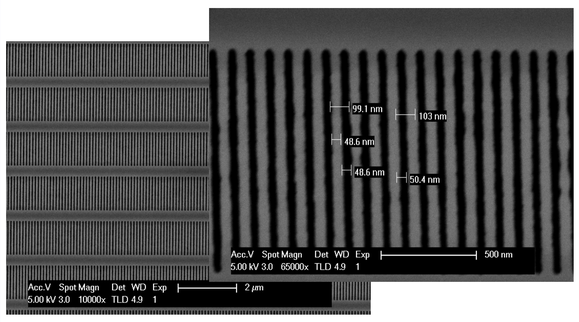


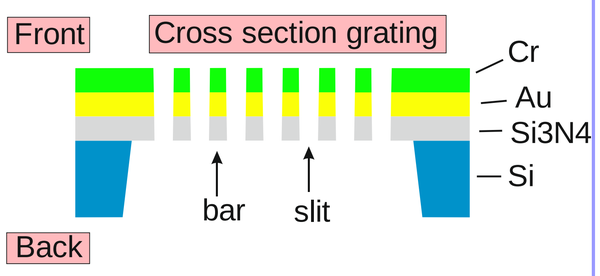


- High spectral resolution
  - $\Delta\lambda$=0.1 nm at 13.5 nm
- Fast switching between high resolution or wide spectrum Wide spectral range, EUV to UV, without breaking vacuum
- Flat-field spectrum
- Higher order suppression by filters



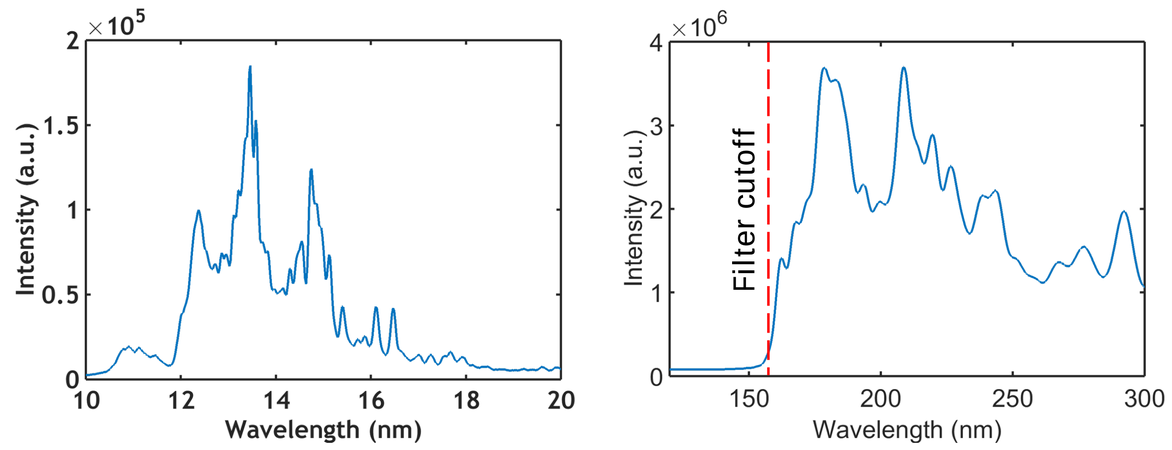
Free-standing Transmission Gratings





- Flat efficiency curve from 10 nm to 100 nm
- Diffraction efficiency in the first order ≈ 10%
- Available gratings on a single chip with line densities:
  - 500, 780, 1500, 1850, 2500 lines/mm and from 1000 to 10.000 lines/mm (by steps of 1000 lines/mm)
- Large grating set provides wide working range of the spectrometer spanning from EUV to UV wavelengths
- Reproducible fabrication of gratings by proprietary process
  - Fine patterning process based on UV nano-imprint lithography
  - Deposition, lift-off and back-etching for releasing the gratings

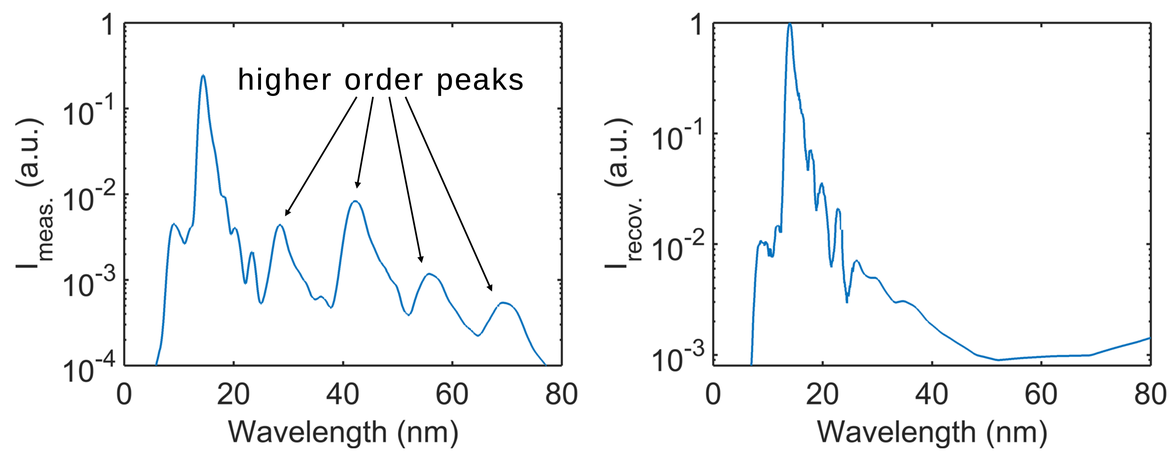
Measurements

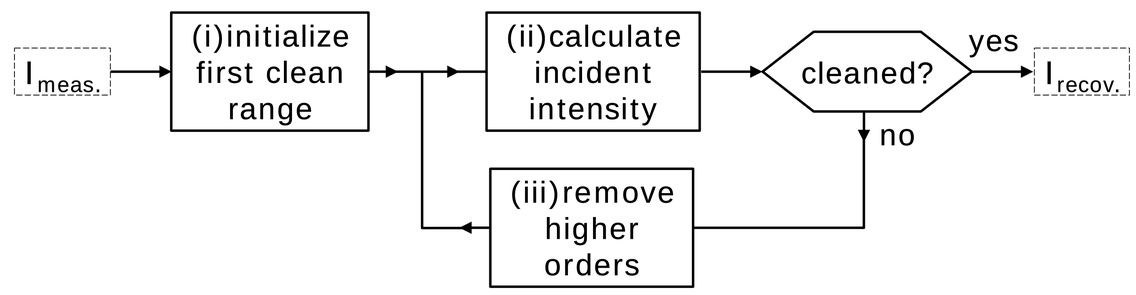


- Discharge produced plasma source with Ne gas
- Fine spectral features resolvable in EUV
- DUV spectrum recorded with fused silica filter (cutoff ~160 nm)
- Measurement both in the in-band (EUV) and out-of-band (DUV)
- Switching between EUV and DUV without breaking vacuum

Mitigation of Higher Diffraction Order Contamination

- Simulated tin spectra





(i) Initialization: Determine wavelength range $\lambda \leq \lambda_0$ that has negligible higher order contribution, so range $\lambda_0 < \lambda \leq 2\lambda_0$ is clean.

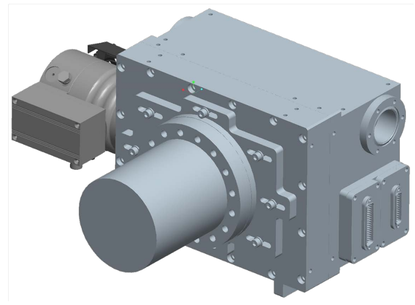
(ii) Calculate incident intensity in the range $\lambda_0 < \lambda \leq 2\lambda_0$.

(iii) Remove higher order contamination in the adjacent range $2\lambda_0 < \lambda \leq 4\lambda_0$ caused by the range $\lambda_0 < \lambda \leq 2\lambda_0$.

- Repeat steps (ii) and (iii) until the complete spectrum is cleaned

Summary and Outlook

- Measurement of EUV spectrum enables optimization of EUVL sources for enhancing in-band radiation
- Measurement of UV-EUV spectrum allows quantification of OoB radiation
- Compact design due to transmission geometry based on grating chip containing a set of high-density gratings
- High-resolution spectrometer covering a broad spectral range from UV to EUV wavelengths by stitching the spectrum recorded by set of filters and cleaning higher order contamination



New compact design

[1] S.J. Goh, et.al. *Opt. Express.*, vol. **23**, no. 4, pp. 4421-4434 (2015).
[2] M. Bayraktar, et.al. *NEVAC Blad*, vol. **54**, no. 1, pp. 14-19 (2016).

This work has been enabled by the FOM Valorisation Prize 2011, awarded to Fred Bijkerk and NanoNextNL Valorization Grant awarded to Muharrem Bayraktar in 2015.